

## PART II

### A LECTURE ABOUT EINSTEIN

Albert Einstein<sup>1</sup> was universally lionized during his lifetime, perhaps more so than any scientist in modern times.

It is hard to describe the storm that broke loose around him in Berlin, where I also lived, after World War I, in late 1919, when his theory of relativity began to be talked about, everywhere, anywhere, anytime, in academic halls and in beer halls. The waves of the storm spread quickly all over the world. Newspapers talked about him and reported on his movements for years on end.

Nothing detracted from his standing. In Berlin it was taken for granted that his mannerisms were all publicity devices. His wearing long hair was jocularly ascribed to a competition against the similarly coiffed playwright Gerhard Hauptmann, 1912 Nobel Prize winner for plays on social themes. Around 1926 an older mathematician who had observed him over many years remarked to me that Einstein was his own best and most watchful publicity agent. But none of this was intended to impugn his greatness, nor did it affect the adulation of him.

In this country the *New York Times* began to report on him in 1920.

In 1926, Mrs. Josepha Wheeler, daughter of the eminent American astronomer Simon Newcomb, solicited from Einstein, then in Berlin, a statement about her father's work to be deposited with his papers in the Library of Congress. Einstein did respond with a statement, praising Newcomb's work towards explaining deviations of planetary orbits from their elliptical Keplerian paths due to gravitational interference from other planets.<sup>2</sup>

In 1929 Einstein wrote a paper on Unified Field Theory, one of several attempts, none of enduring outcome, to force all of physics into the mathematico-physical mold of his theory of gravitation. As I remember it, the American newsmen in Berlin burned up the transatlantic cables transmitting the entire text of the paper to the United States, intricate formulas and all. This account is from my memory. But it is a documented fact that a trustee of Wesleyan Uni-

versity purchased the manuscript directly for deposit at the Olin Library at Wesleyan.

Abraham Flexner, the first director of the Institute for Advanced Study in Princeton, liked to regale young people with stories of his exploits. I was sometimes present, being a member not of his Institute but of Princeton University. Sometime in 1934 he told us how he persuaded the Bamberger Family of Newark, New Jersey, to come across with a donation to found the Institute. It was in 1931, and nobody was willing to make money commitments. Finally the patriarch of the clan blurted out: give us Einstein and you can have your Institute.

And I do remember that probably late in 1931, newspapers in Germany reported that henceforth Einstein would be dividing his time between his position in Berlin and a lush academic sinecure in Princeton, U.S.A.

When late in 1933 he was sailing from Europe for permanent residence here, at the pilot stop in New York harbor two trustees of the Institute took him off the steamer in a tugboat for quick processing in the port.

Finally, during World War II, at a war bond rally in Kansas in 1944, a manuscript copy of Einstein's 1905 paper on special relativity was sold for six million dollars and deposited in the Library of Congress.

Why Einstein should have received such public attention and esteem is, I think, an intriguing problem in mass psychology. After all, Einstein did not write a treatise like Darwin's *Origin of Species*—which, as I remember it, the contemporary *New York Times* called a book in a century—or, if this be too controversial, like Newton's *Principia* (that is, *Mathematical Principles of Natural Philosophy*), the like of which has not been created before or since. For instance, the *Principia* predicted that some day a projectile would be launched with a sufficiently high velocity to make it an earth satellite. This was seriously spoken of in the eighteenth century, even though it came true only in the middle of the twentieth century. I do not think that there is anything like this in the writings of Einstein. In a splendid paper of 1916 Einstein recognized the existence of *stimulated emission* that decades later became a pillar of the theory of lasers. But the paper had no predictive features.

Newton also wrote a book called *Opticks* which, according to Marjorie Hope Nicolson, inspired sages and poets through the length of the eighteenth century and beyond.<sup>3</sup> Einstein wrote nothing of the kind. The *Opticks* is based on the resolution of white light into the visible spectrum from red to violet, together with related experiments. Newton performed all his experimental feats himself, as did other great physicists after him. Maxwell, for instance, however eminent a theoretician, was also the first professor of *Experimental Physics* at Cambridge University. But Einstein never performed an experiment in his life. Einstein spent twenty-two years at the Institute for Advanced Study, but he never formed a school of modern physics, whereas Niels Bohr directed such a school of world renown.

Einstein never coined an original name for anything. He created the elementary particle "photon," calling it a "quantum of light." The beguiling name *photon* was coined by somebody else. Even his "principle of relativity" was not his by name, but Poincaré's. Heisenberg, at the age of twenty-four or twenty-five, proclaimed an "Uncertainty Principle" that scared the daylights out of some philosophers. Einstein never came up with anything so suggestive. I know only one aphorism of his worth remembering: "As far as the laws of mathematics refer to reality they are not certain, and as far as they are certain they do not refer to reality." Interesting as it may be, it does not have half the punch of the cognate saying that "mathematics is the field of knowledge in which nobody knows what it is that he is talking about," which I think is due to Bertrand Russell.

An awareness of the fact that Einstein was, after all, a product of a period is beginning to seep through. The National Academy of Sciences in Washington, D.C., has recently decided to erect an out-of-doors monument to Einstein. I have no quarrel with this at all. Einstein became not only an American citizen, but also an American property. After World War II many immigrant celebrities started dashing about all over Europe, usually ending up in Switzerland, where at that time they could get creature comforts approximating those in the United States. Einstein, however, stayed put in Princeton, officially at any rate, and the community, in all its strata, was very appreciative of this. When he died in the Princeton Hospital, right at home, a blanket of sadness spread over the town. Thus a monument to him is well deserved. But the prospectus of the Academy soliciting contributions towards the erection of the monument is surprisingly circumspect. It bills him as the greatest theoretical physicist of the twentieth century, as if shunning a comparison with a nineteenth-century physicist like Maxwell, or with a twentieth-century scientist other than a physicist—say a Sigmund Freud, who would be formidable competition indeed.

Still, with all possible qualifications duly noted, Einstein was a person of really great impact, not only on physics but also on philosophy, as even a schematic presentation of his achievements ought to put beyond doubt.

Einstein's span of high creativity extended from 1900 till 1920, when he was forty-one, or, if one wants to include the Bose-Einstein statistics, till 1924 when he was forty-five. This seems typically to be the approximate productive span for persons of his caliber. Maxwell died at forty-eight, and Riemann, but for whom there would be no Einstein gravitation, at less than forty. Gauss managed to lay the foundation for Riemann's pre-Einstein memoir when he was approaching fifty. Newton published his *Principia* at forty-five, and his contemporary Spinoza died at forty-five. Galileo crested at the age of forty-six with his *Starry Messenger*, which created the telescopic depth of the universe. His contemporary Johannes Kepler terminated his high creativity with his third planetary law at about forty-seven, and Galileo's and Kepler's contemporary William Shakespeare retired from London to Stratford at forty-eight. Before

Shakespeare, Giordano Bruno was incarcerated by the Inquisition at the age of forty-four; and long before him Thomas Aquinas amassed a shelf of writings amidst an active career in church policy before dying at the age of forty-eight or -nine. There were notable exceptions though: Miguél de Cervantes, a contemporary of Shakespeare, was already fifty-eight when the publication of *Don Quixote* plunged him into immortality. Also, Immanuel Kant of Königsberg was about fifty-eight when the publication of the *Critique of Pure Reason* made him a successor—some would say *the* successor—to Plato of Athens.

Einstein's creative span from 1900 till 1920 is neatly divided in two halves by the First Solvay Congress of 1911. These Congresses, founded by the manufacturer of sodium carbonate Ernest Solvay, meeting in Brussels, and having about twenty-five participants each, are resplendent with famous names, and the first was particularly star-studded. Einstein, at thirty-two, was the youngest participant, and James Jeans, at thirty-four, the next youngest. These two "juniors" were charged with reporting on the bad state of health of the Dulong-Petit Law about specific heat, with Jeans presenting the patient's past history in the nineteenth century when ministered to by Maxwell and Boltzmann, and Einstein explaining the fancy remedy, quanta and all, prescribed by himself in 1907. It leaps at the reader of the Proceedings of the Congress that luminaries like Lorentz, Poincaré, Planck, Nernst, and W. Wien were profoundly impressed with Einstein, and were so indulgent with him. He talked a great deal, and butted in at will. And the luminaries beamed at him, at whatever he said. In return, Einstein was quite deferential in letters to them (less so in letters about them).

Poincaré died soon after, which made it the easier for Einstein to outshine the others within a decade, shining them out of existence, as it were. In a way, they did it to themselves. Only two years after the Congress, in 1913, Planck, speaking for the German delegation to the Congress, told some Prussian authorities that Einstein was a physicist in a century, and *must* be brought to Berlin. He was made both a salaried member of the Prussian Academy of Sciences with the privilege of lecturing at the University (the two buildings are, or were, close by) and the director of a separate research Institute of Physics whose creation was hastened by his appointment. All this at the age of barely thirty-five, in the spring days of 1914 before the outbreak of World War I, even before Einstein was ready to present his *pièce de résistance*, the theory of General Relativity and Gravitation, which, incidentally, as some rumor had it, Planck abhorred.

Einstein did indeed lecture at the university, making it a platform for the propagation of the faith in relativity and himself. I attended such a lecture in 1919, sixty years ago, and I vividly remember part of what he said, and certainly how he said it. From time to time, in any lecture or debate, he would

look up above the audience, as if actually communing with the powers above, but letting the audience be witness to it.

In content, what I remember most about the lecture was a sharp upgrading of the stature of Michael Faraday. Nowadays there is a Newton-Faraday-Maxwell axis, and I think that Einstein contributed greatly to its creation. At the beginning of the century Faraday was not included in such an exalted company. Even in the late 1930s an Oxford don, a humanist visiting the Institute for Advanced Study at Princeton, told me how enlightening it was for him to learn in Princeton of the great esteem that Faraday enjoyed in the U.S.A. Einstein in his lecture gave Faraday much credit for the creation of the electromagnetic field, even if the lines of force in the field had the material quality of strings or even cables for him.

But now for Einstein's real achievements.

In 1905, at twenty-six, he published, in one and the same volume of the *Annalen der Physik*, three papers, each now enshrined in fame. In the first paper he introduced, but for the name, the universal *photon* as an elementary particle much as it is understood today. Its only rival was the electron, which, although long known, had been institutionalized as a kind of elementary particle in our present-day sense about ten years before. The most notable point of the paper is that Einstein satisfactorily explained the way in which these two rivals interact in the so-called photoelectric effect. It was this paper that brought Einstein the Nobel Prize in 1921; at least, no other achievement is singled out in the citation. Using the technique of this paper, Einstein began in 1907 to repair the Dulong-Petit law. He carried the repair only halfway, Einstein himself pointing out an imperfection. Debye and others completed the job.

In the second paper of the same volume of the *Annalen*, and in some follow-up papers, Einstein gave a satisfactory theoretical account of Brownian motion, which is the random motion of particles suspended in liquids. The magnitude of this achievement is not dimmed by the fact that, independently of Einstein, Marian Smoluchowski<sup>4</sup> in Cracow did something similar at the same time, and that subsequent theories of Brownian motion, some quite elaborate, were on a different level of mathematical expertise.

The third paper in the volume was the noisily celebrated special theory of relativity—universally celebrated, that is, till 1953, when Edmund Whittaker, in a masterful history of physics, rudely stripped the paper of celebrity and reduced it in rank to a glorified footnote to what Whittaker called “the theory of relativity of Poincaré and Lorentz”; but in the matter of general relativity and gravitation he left Einstein's standing intact, offering, in fact, an excellent sketch of the theory. The anguish of Einstein partisans notwithstanding, most physicists are tending to acknowledge that Whittaker is not entirely wrong, at least in the sense that there were several originators of the theory and that Einstein was a relative late-comer.

For my part, I do assign to Einstein an outstanding share in the discovery of special relativity, because Einstein's paper contained a philosophical blockbuster that had a very salutary effect when it exploded, somewhat belatedly in 1919, on the agora of philosophers and bystanders. It was the philosophical question of what it means to say that two events at different locations in space are synchronous, and how one "verifies" this, the matter of verification being of course the heart of the question.

Surprisingly, philosophers did not resent the intrusion onto their turf by a professional outsider. Many of them were exhilarated, on the Continent at any rate. None dared to spurn it, "lightweight" as it was when compared to customary "heavy" stuff like ethics, aesthetics, mind-and-body, existence of God, transcendental knowledge, etc. Some of them might even sneak Einstein's question into their so-called "Introduction" to philosophy, a grab-bag of what a budding philosopher ought to become familiar with. Einstein's kind of question was not quite unprecedented. Immanuel Kant once asked whether it is meaningful to say that a treasure is buried in the Sahara in a location inaccessible to humans. But these were marginal questions in exotic settings. Nothing can be more common than wanting to know whether two events in different cities have occurred at the same time, however, and, if they have, wanting to establish this in a manner that will stand up in court.

I can cite a witness to the impact of the question. It is Sir Karl Popper, widely known for his book *The Open Society and Its Enemies*. I remember reading in an autobiographical account of his that it was Einstein's special relativity, especially the question of synchronicity, that made him into the philosopher he has become, except that it suited his philosophical temper to feature not "verifiability" but "falsifiability," as a criterion for the validity of any theory, that is.

Formally, special relativity is an alternate to Newtonian mechanics, but different from it. It contains a positive constant  $c$ , and Newtonian mechanics arises as a limiting case by letting  $c$  go to infinity. By pedigree, however, special relativity was an outgrowth of and even a part of electrodynamics. Lorentz and Poincaré so viewed it, and they included the problem of synchronicity somewhere in their context, as a problem of physics. But Einstein was the first to make it clearly into a problem of knowledge in general. I find that Einstein always thought in this manner. This was his *modus operandi* throughout his entire career, scientific and other, usually for the good, but not always. It made him extremely apt to be successful for the present, but less enduring as a prophet. We will return to this distinction later.

Einstein was what I venture to call an "essentialist." He had the drive and capacity to single out, in any scientific situation under purview, what is really *essential* to the context, not only neutrally, but also in the hierarchical order of its components, and in its scope.



Einstein arrived at the universal photon in this way. The name *photon* was introduced much later, by G. N. Lewis in 1926. As I have already stated, Einstein himself spoke of a "quantum of light," because he sifted its existence out of Planck's quantum theoretic explanation of black body radiation. In fact, in the 1916 paper mentioned before, by penetrating through to essentials, Einstein even gave the simplest proof yet known for Planck's radiation formula from Planck's own premises.

Or, consider the famous formula  $E = mc^2$ . It was actually found by Poincaré, but presented by him without derivation or explanation. Einstein, however, after proving it, gave it the universal interpretation that if a physical system, any system, loses energy, then it also loses inertial mass. The amount of that loss is  $E/c^2$ , with the implied suggestion to a later generation that, conversely, by atomic or nuclear disintegration of mass a corresponding amount of energy can be liberated. This is precisely what happens in atomic fission or thermonuclear fusion. Because of this universal interpretation, which was heavily emphasized in the so-called *Smyth Report*,<sup>5</sup> the formula has been firmly attached to Einstein, irrespective of its origin in Poincaré, who had stated it in an electrodynamic context.

Even Einstein's gravitation theory, his most original creation ever, was not independent of an essentialist provenance, in Einstein's own pedigree for it, at any rate. He packaged it inside something he called general theory of relativity; this in turn was an essentialist elaboration of something called special theory of relativity, which was designed to feature the fact that light velocity is maximal and constant. And this special theory in turn was an essentialist shell in which to house something that had been created by Poincaré, a principle of relativity, expressly so named by him. This principle had its debut right in this country, on September 24, 1904, when Poincaré presented it at a Congress of Arts and Sciences assembled at the World Exposition in St. Louis. As if this route were not devious enough, on the road from the principle of relativity to gravitation Einstein built a major way station called the Principle of Equivalence, and a secondary one, a Principle of Covariance, both mandatory stopovers; the stopover at Equivalence involved an eerie plunge in the so-called Einstein Elevator.

All this sounds very involved. Nevertheless, the magnitude of Einstein's achievement is such that it can be savored from outside without entering into a maze of technicalities at all.

Gravitation is the oldest and most ubiquitous phenomenon, and it is always accessible to observation. Objects are falling and moving all the time and in all places. But explaining gravitation has always been a forbidding problem. Even today the innermost structure of gravitation is more arcane than anything else in physics, and if you overhear a physicist say that something is only *probably* so, then more likely than not he is talking about gravitation, or something involving gravitation. Thus, some physicists say

incessantly that there “probably” are gravitons (elementary corpuscular particles of gravitational *force*), as if by saying this often enough the gravitons would indeed show up suddenly.

Aristotle proposed a theory in which each body in the universe has its natural place, and if it is not located in it, it seeks to reach it. There was no effective rival theory till the end of the sixteenth century, although dissatisfaction with Aristotle’s theory had been on the increase since the late Middle Ages. In the early seventeenth century Galileo offered a satisfactory explanation, but only for terrestrial events. His paths of falling bodies were even parallel, as if the earth were flat. At the same time Kepler was seeking to explain gravity’s cosmic manifestations. With his powerful intuition he half-guessed the three planetary laws, but an underlying rationale eluded him. Newton then found one, on a comprehensive scale.

The simplicity and grandeur of Newton’s theory fascinated lay intellectuals like Voltaire and unemotional philosophers like Kant. But professionals in astronomy and mechanics had cause to view it soberly, even disenchantedly. When trying to regulate the motions of planets, moons, and comets by the new theory, they encountered difficulty after difficulty. As soon as one difficulty was seemingly over, a new one demanded attention. Therefore there were no discouraging side-glances at Einstein when—after some attempts by others—he started from the very roots, building up something very different, even if it was in close proximity to Newton’s ideas.

From our retrospect, the working mathematics needed for any mathematically controlled theory of gravitation was in Newton’s time still in its infancy, and there was only one space form available in which to create it, the Euclidean. That was all that Newton had to work with, and he made the most of it. Euclidean space happens to be infinite by well-intuited mathematical notions of infinitude. But this does not mean, as some philosopher-historians volubly proclaim, that Newton was intellectually motivated by a metaphysico-theological drive for infinitude of space. Even the fact that Newton viewed his Euclidean space as “absolute” has no such implication for me. If closed Riemannian space had been mathematically accessible to Newton and he had used such a space instead of the standard Euclidean type, then philosopher-historians would have undoubtedly adjusted his alleged metaphysico-theological drive accordingly.

From motives that nobody can fathom, after 1911 (and even earlier) Einstein was driven to erect a theory of gravitation of his own, a genuinely new one. By chance and circumstances he fell in with a body of elaborate mathematics that had come into being long after Newton, in the course of the nineteenth century. As if by a predestined harmony, it was highly fit to articulate Einstein’s desiderata from physics and give suitable responses to them. It was the so-called Riemannian geometry, that is, the multidimensional differential geometry mainly of Riemann, but indispensably also of Christoffel,



Beltrami, Ricci, and Levi-Civita. The mathematician Marcel Grossmann, an old acquaintance of Einstein's and a faculty colleague at Zurich, was Einstein's mentor and even co-author in a few papers. But the final theory, and above all the inspiration, drive, and passion of purpose, were wholly Einstein's. At any rate, there are no reports of Grossmann having had the sense of a brush with immortality followed by failure due to Einstein's ill-will. Einstein did exhaust his store of mathematical knowledge, but any physicist has the privilege of doing so with any mathematician. Einstein was after big game, and he applied whatever hunting laws were legitimate.

When mathematicians became aware of this activity in a highly charged mathematical area, their curiosity was aroused, and David Hilbert, the greatest among them, set out to rob Einstein of his prey. In defense, or rather counter-attack, Einstein tore the center piece out of his kill, left the denuded carcass for mathematicians to argue over, dashed off into the promising field of cosmology, and very quickly inaugurated a novel kind of cosmological speculation of which he became the father or godfather for the rest of the century. This was a glorious evasive tactic, and it was Einstein's all-overshadowing enterprise, uniquely his, although mathematicians hesitated to follow Einstein, and even physicists were skeptical. I heard it said that Niels Bohr warned his followers to stay out of cosmology until problems of microphysics have been solved. This is like saying that one should defer space exploration until urban slums have been cleared.

Again, the effect of these developments on philosophy was incalculable. Since Giordano Bruno in the sixteenth century, the space problem involved in astronomy and cosmology was philosophically beset by an utterly sterile yes-or-no question: whether space is finite or infinite and also what infinitude of space means cognitively. Some philosophers of science are clinging to this question even today. Aristotle was naively condemned for finitude, and Bruno was even more naively hailed for infinitude. Those in the know, the true cognoscenti, were mostly hedging. Copernicus hedged—and this was one of his finest features; and so did Galileo, from indecision. Kepler inclined towards finitude, but less from siding with Aristotle than from disapproving of Bruno, whose brand of infinitude he considered astrophysically reckless, and rightly so. Descartes created his own wrinkle and hedged by making his so-called extension (*extension, étendue*) neither finite nor infinite but indefinite, which, in its inventiveness, went back right to Anaximander. Newton in the *Principia* was fully hedging, avoiding a decision throughout the three editions. When the rector Richard Bentley in a pesky letter tried to force Newton's hand by making him agree that a universe of finite matter might suffer gravitational collapse, Newton hemmed and hawed and counter-suggested that such a universe might remain stable by arranging itself in what is nowadays called gravitational clustering. And Immanuel Kant weaseled out of the situation some of the time by devising an antinomy that if the world

is infinite it is finite, and if finite infinite. Among medieval schoolmen such antinomies must have been quite common. Any trained schoolman could probably make up one on any contrariety offered. Kant himself used several.

To my surprise, Ludwig Wittgenstein was quite conventional in this matter. The logical space of his *Tractatus* is, by parenthetical remark, infinite. Commentators notwithstanding, this infinitude serves no purpose, but is the standard philosophical presumption since Giordano Bruno.

Einstein changed all this by abolishing the traditional presumption that the universe is the infinite Euclidean space or a finite portion of it. Instead he approached the outlook of Riemann that almost any topological manifold should be eligible to begin with. A compact manifold, for instance, offers a neat compromise between finite and infinite, and Einstein gave attention to the simplest such case, namely, the case of a sphere. Also, it is not necessary to elect one fixed space and adhere to it. One may envisage a family of spaces and examine how observational and speculative data are compatible with all of them or some of them. As a consequence, even the problem whether the universe had an origin in time, in a cosmically meaningful gauge of time, or has been in an eternal state of existence, appeared in a very new light. All in all, as I remember it, one felt one was finally free after centuries of constriction in a straitjacket of presumptions.

Of course, curved spaces were introduced in the nineteenth century, long before Einstein. However, the renowned hyperbolic space of Bolyai-Lobachevsky is topologically not different from Euclidean space and made no immediate impression on physics, or even on mathematics. But the elliptic space of Riemann did draw a quick response. Soon after Riemann's memoir became known in English, Simon Newcomb, whom I have previously mentioned, in an 1877 paper in the prestigious *Crelle Journal* speculated on how elliptic and even projective space would be detectable by human or astronomical experience. Also, in 1900 an astronomer, Karl Schwarzschild, went into greater quantitative detail. Yet these papers were of no enduring consequence, because they dealt with the same physics as before, only in different spatial frameworks. But in 1916 the same Schwarzschild, in response to the latest work of Einstein, constructed a relativistic space-time model whose importance is such that Schwarzschild's name, I think, currently occurs in cosmology more frequently than Einstein's. Regrettably, he died soon after, at the age of forty-three.

A similar early contribution to relativity was made by Willem de Sitter. In addition to scoring specific achievements, he also wrote in 1932 a small general book called *Kosmos*. In it he makes a statement that should be emblazoned on all books in physics or astronomy. It is the statement that "Infinity is not a physical, but a mathematical concept."<sup>6</sup> That is, whenever you state in exact science that some physical magnitude is infinite, then, without exception, you refer to a quantity in an appropriate mathematical

skeleton of the physical context. Without a mathematical skeleton, however primitive it be, no such statement can be made. This in itself does away with many a version of the query whether the universe is finite or infinite.

In comparison to Einstein's gravitation, Newton's appears to be simplistic. But it is wrong to say that Einstein "overthrew" Newton. Einstein used mathematical resources, readied by others, that would have been inaccessible to Newton in his wildest dreams. Newton was still so ingenuous in the ways of analysis that he took it for granted, half-apologetically, that his gravitational force was an action-at-a-distance, not knowing that the simple analytical device of introducing the gravitational potential turns it into a proximity-action, instantly. In fact, the gravitational potential as a dominant concept revealed itself only in the early nineteenth century in the work of Poisson. Einstein himself stated very expressly that, *mathematically*, what he did was to replace Poisson's one-component-object by a more elaborate object of ten components.

Einstein's advance over Newton was evolutionary, and nothing but evolutionary. He overthrew Newton as little as did birds overthrow reptiles out of whom they evolved. In fact, reptiles continue to flourish alongside birds, as does Newton's gravitation alongside Einstein's, for instance, in all engineering mechanics and physics in our time. The theory and production of high velocity particles prerequisites special relativity, but particle accelerators in which they are generated are architecturally built on Newtonian engineering mechanics exclusively. As Niels Bohr put it in general terms: "No more is it likely that the fundamental concepts of the classical theories will ever become superfluous for the description of physical experience."<sup>7</sup>

Einstein did not overthrow Maxwell either. In fact, it can be argued that special relativity was an apex achievement evolving almost rectilinearly out of Maxwell's electromagnetism, and all but completed it.

Nor can it be maintained that Einstein was superior to Maxwell in an overall sense. It is true that, except for his study of the ring of Saturn, Maxwell did not contribute directly to the study of gravitation in which Newton and Einstein excelled. But he did perform the extraordinary feat, to which there is no parallel, of fusing optics with electromagnetism. Optics, Aristotle's *hé optiké*, was the most venerable body of knowledge there was, and everybody who was somebody, literally everybody, felt bound to have an outlook on it—physical, philosophical, even inspirational—in late antiquity, the Middle Ages, the seventeenth century, the eighteenth century, etc. Electromagnetism, however, William Gilbert notwithstanding, was an upstart field; the Leyden jar was the perennial toy for adults. Yet Maxwell fused these two fields into one, or, at any rate, consummated their fusion. In the process he created, with posthumous assistance from Hertz and others, the awe-inspiring electromagnetic spectrum from end to end, from frequency 0 to frequency  $\infty$ . To appraise its importance one need only consider what would be left of labora-

tory physics, red-shift cosmology, and radio-astronomy if it were not available. To offset this achievement Newton at least wrote his two tremendous works, the *Principia* and the *Opticks*, on which Voltaire could compose a beguiling commentary. Einstein wrote nothing to induce Arthur Koestler to include him among his sleepwalkers.

Any survey of Einstein's scientific career, however sketchy, must also take into account activities in his later years, after the high creativity had exhausted itself, but the glory and the presence remained. His scientific later years lasted at least three decades, beginning not later than 1925, although he continued to bask in glory for another ten years or so before gradually becoming an "institution" resting on past achievements.

Einstein's later years had a regrettably negative scientific cast. If, as I have maintained all along in this essay, the nineteenth century lasted from the French Revolution and Napoleon till the end of World War I, then, in physics, Einstein was a perfect embodiment of the last two decades of it, shining brilliantly forth into the twentieth century that came afterwards, but not being able to see into it himself, as if the light that he threw into it flashed back at him, blinding his vision. In this sense Einstein was a person of the present, of the lived present and the escapist present, and it was this that made him, especially in this country, a smash hit of the 1920s.

But he was not a prophet; he did not have the passion and vision, selflessness and calling, to be one. Between 1925 and 1927, a crew of post-teenagers, headed by Heisenberg, Schrödinger, and Dirac, seized the helm of the ship of quantum theory, set out into uncharted waters, and, to the amazement of many, started making discovery after discovery, not only of islands, but even of continents, and of new navigational principles too. This was the so-called new quantum theory. Mathematically, the "classical" equations of mechanics and electrodynamics that had emerged from the work of Newton, Euler, Lagrange, and Maxwell were radically re-interpreted, and the effect on the open mind was compelling and irresistible.

Einstein, amazingly, resisted and remained aloof. He soon became antagonistic to the new discoveries, and gradually more rejectionist. He could not or would not perceive that a momentous development in a new phase of modernity was in the making. He refused to legitimize it, in whole or in any part, and stuck to his refusal to the end, pleas by personal friends notwithstanding. There were no overt public demonstrations, no excommunications of heretics, just a hard standoff, and an agreement to disagree reluctantly maintained.

There were debates, though. Einstein, being unbeatable in debates, scored on points, sometimes markedly. And like a medieval schoolman, he was content with this kind of victory and the applause of his retinue. But, before the God of Physics, his were illusory victories. The new quantum theory was couched in a new idiom, subdivided into dialects. Its grammar is not yet settled, even today, to the satisfaction of all the faithful. This bespeaks strength,

not feebleness. For instance, analysis was a new idiom for mathematically controlled science. It suddenly sprang up close to 1600, and immediately came up with Kepler's remarkable planetary laws. But it went through the pangs of birth, childhood, and adolescence for over two centuries before reaching the adulthood of rigor and consistency in the nineteenth century, and at first it had many more vulnerabilities than anything that Einstein could adduce against the innovations of his day. One can only pity a twentieth-century student of Kepler bent on making twentieth-century sense out of the ramblings of Kepler's *New Astronomy*. Yet the achievements of Kepler are here to stay. Einstein should have known that a debate or two will not topple something destined to stay, but, alas, he did not. Whether he could not or would not know it is hard to determine, and does not make a great difference anyway.

There were specific findings to which Einstein and a small band of other physicists were dialectically opposed, as some still are. The primary one is Heisenberg's Uncertainty Principle taken in conjunction with Born's probability doctrine. It states that in the case of an elementary particle, say an electron, its position and its momentum (that is, velocity) cannot be, both of them, observed with sharp precision at the same time. If, say, the position has been fixed absolutely, then the momentum is entirely random; joint approximations of the two have thresholds beyond which they cannot be improved, every threshold involving Planck's constant of action; and if one of the two has been observed to fall within a certain range, then the value of the other has possibilities that are given by associated probability distributions.<sup>8</sup>

These assertions about limitations of microphysical observability produced in Einstein and a handful of other physicists an emotional reaction as if a sacrament hallowing the concepts of space and time had been defiled. Also, pragmatically Einstein must have instantly perceived that this was the end of his dream of a Unified Field Theory *on his terms*, although for years on end he would go through the motions of trying to find one; and it was perhaps this that he would not ever forgive. While only some scientists balked, many more philosophers were dismayed. Until 1927, when Heisenberg proclaimed his Uncertainty Principle, professional philosophers took little notice of quantum theory, of the "old" theory and even the "new" one. But this apparent contravention of the customary presumption of determinism in the laws and prescriptions of physics took them by very unpleasant surprise and jolted them into attention. It was one thing say, to oppose Hegelianism to Kantianism, old or "neo-"; but it was quite another thing to call nineteenth century determinism into question. An Einstein could afford just to stand aside and pout. The philosophers could not. They had to get into the scrimmage and try to explain things to themselves and others. For instance, Popper wrote a lengthy article about it, and the distinguished philosopher Ernst Cassirer, author of a string of important works, added one last book to his list, to deal with deter-



minism and indeterminism in physics. From what I have seen, these philosophers' cogitations have not been overly illuminating so far.

From my viewpoint, their lack of success does not reflect on the new physics or the struggling philosophers, nor does it justify Einstein's aloofness. The new quantum theory is finally a creation of the twentieth century proper. It expresses the vicissitudes and anxieties, the fears and uncertainties of our age much more faithfully than did the old theory, and professional philosophy will have to find the drive and the idiom by which and in which to articulate this.

The nineteenth century knew a great deal about discontinuities, and it spiced the naiveté of the eighteenth century by inserting "additives" of discontinuities, some good-sized, into its philosophemes about continuity all around. But these added discontinuities were somehow felt to be undesirable, even if ineluctable, and continuity remained the paramount wish and expectation, even more intensely than in the eighteenth century. In fact, academics have been wont to proclaim that the nineteenth century was *the* century of continuity. Although Darwin's continuist evolution had to be salvaged from immobilizing rigidity by an injection of potent mutationist discontinuity, overall continuity nonetheless remained paramount. Bernhard Riemann, one of the gentlest of men, in a paper of 1860 inaugurated thought patterns and even words of violence that only twentieth century technology was able to follow up. He did not have "shock wave" in his vocabulary, but he had "compression wave" (*Verdichtungswelle*) and "compression thrust" (*Verdichtungsstoss*); yet the world around him took little notice of his anticipation. Karl Marx envisaged a violent socioeconomic upheaval, that is, discontinuity, to come. But it was sociopolitically predetermined and bound to be followed by a future free of such discontinuities. And Marx bitterly fought anarchists, that is, advocates of political discontinuity as a way of life.

But as the twentieth century wanes, discontinuities are gradually advancing to a level equal in day-to-day importance to that of continuities. They are becoming severally and jointly a way of life and thought throughout, and not only in select areas. Einstein had no qualms about imputing to elementary particles two co-existent aspects, a continuous undulatory aspect and a discontinuous corpuscular aspect. And he had no objection to, but productively cooperated in the large nineteenth-century statistical theory of matter that takes into account the difficulties of truly precise observations and the mathematical inconvenience of dealing rigorously with a mechanical system of many particles. But he balked more than half of his academic life at the Born-Heisenberg statistical theory, because its statistical aspect is not marginally approximative but centrally legislative.

And yet, already decades before Born-Heisenberg, the American philosopher Charles Sanders Peirce (1839-1914) perceived, from pure thinking as it were, the possibility of an "absolute chance," that is, of a genuine indeter-



minacy as opposed to an indeterminacy arising merely from "ignorance," be the ignorance genuine or presumptive. Peirce even installed the minor Greek goddess *Tyche* (chance) to be in charge of this "Tychism."<sup>9</sup>

Niels Bohr, only six years younger than Einstein, proposed to come to grips with the perplexities of twentieth-century physics by the use of a new rule of comprehension, a tricky one. He called it the principle of complementarity. By this principle there are near-contradictory aspects in the process of verifying phenomena. Yet, however contradictory, the aspects complement each other. If an experiment illumines one aspect it necessarily obscures the other. On translating from experimentation to cogitation it follows that there are theories that are both contradictory and complementary.<sup>10</sup> As if to corroborate this, there are physicists who find that relativity theory and quantum theory are of this kind.

This sort of thinking was outside Einstein's horizon. Before World War I certain intellectual circles hopefully expected that a common language of communication, a true Esperanto, would cure many if not all ills of the world; and Einstein's heart was arrested in this expectation. But it is a vain expectation. In our century there is a built-in possibility for ambiguity and uncertainty that cannot be eliminated. Gödel's theorem, when boldly transferred from Logic to Life, already points to this, whether Gödel himself would approve of such a transfer or not. Suppose the United States and Russia would agree, in the purest of intentions, to draw up a detailed comprehensive document of coexistence in the most precise language possible. By Gödel's theorem no precaution of wording can prevent situations from arising about which it could not be decided whether they are or are not subsumable under the provisions of the document. An equally bold transfer of the principle of complementarity suggests that subsumability in all cases could be insured by composing the treaty in two versions, English and Russian, but at a price: The price is that in some instances conflicting interpretations might arise, either outright contradictory, or differing so much in degrees of clarity as to amount to a contradiction. Albert Einstein, physicist *sans pareil*, could not or would not see what was quintessential in the workaday doings of a younger generation of physicists all around him.

Bertrand Russell, with whom Einstein was in rapport, was not far different from him. Russell's great disciple Ludwig Wittgenstein did have a sense of something new in the offing. His *Tractatus* was done at the same time as Einstein's work on General Relativity, and fits snugly into the outgoing phase of the extended nineteenth century. After that, Wittgenstein began to grope for something radically different, towards entering into the twentieth century proper, as I see it; this is shown by the difference of style in his *Philosophical Investigations*, and in the *Brown* and *Blue Books* before. But he could not make it. His intellectual resources were too limited and too exhausted for such a radical reorientation.

Kafka and other existentialists, with the Sigmund Freud of around 1930 among them, did show an awareness of a rising Discontent in Civilization, but they were too continuity-bound, too conditioned and too overwhelmed by the past effusions of Schopenhauer, Kierkegaard, and Nietzsche, to recognize the twentieth-century novelty of it all.

Even Arnold Toynbee, when he tried to extrapolate from the past into the future, did not have things in focus. Too much eschatological mysticism clouded his vision. But his rival prognosticator Oswald Spengler, author of *The Decline of the West*, clearly described the woes of our "imperial presidency," for instance, and he clearly foresaw the oncoming struggle between the West—which he calls the Faustian culture—and a resurgent Russia. What is more, he insisted before 1918 that in the end it will be not the Lenins but the Solzhenitsyns that will oppose us.

The contrast between the nineteenth and twentieth centuries can be epitomized by a changing of the guard in *Central Europe*, and I mean Central Europe literally. In the extension of the nineteenth century there were Freud, Einstein, Spengler. Their counterparts in the twentieth century proper were Kafka, Heisenberg, Gödel. Overwhelming as the nineteenth century is in this confrontation—and it was an overwhelming century indeed—the twentieth century does have a very distinctive composition and orientation of its own, a radically different one. How the twenty-first century will compare with the two preceding ones will be for the twenty-first to decide.

## NOTES

1. Albert Einstein was born March 14, 1879, in Ulm, Germany, and died April 15, 1955, in Princeton, New Jersey. He was cremated and his ashes were scattered, except for the brain, which has been preserved.

After an irregular attendance at high schools in Munich, Germany, and Aarau, Switzerland, he was enrolled at the reputed Zurich Institute of Technology ETH (Eidgenössische Technische Hochschule) from July 1896 till August 1900, graduating from its Division IV with a diploma for teaching mathematics and physics. After temporary teaching jobs he became on June 23, 1902, a clerk at the Patent Office in Bern, from which position he resigned October 15, 1909, to become an associate professor (Extraordinarius) at the University of Zurich. Until joining this university, while still with the Patent Office, he was also a *Privatdozent* at the University of Bern. He left the University of Zurich in the summer of 1911, to become professor at the German University of Prague. He stayed only one year, 1911/1912, leaving to become full professor (Ordinarius) at the ETH, upon the recommendations of Marie Curie and Henri Poincaré. This stay was also brief, and from April 1, 1914, till the middle of March 1933 he was a salaried member of the Prussian Academy of Sciences in Berlin. In October 1933 he reached his final academic destination. He joined the Institute for Advanced Study at Princeton, New Jersey, as one of its faculty members, becoming a resident Emeritus in 1946.

These data are taken from Max Flückiger, *Albert Einstein in Bern* (Bern, 1974), and the comprehensive biography of Einstein: Ronald W. Clark, *Einstein, the Life and Times* (New York and Cleveland: World Publishing Company, 1971).

Some data in the text have been taken from the bibliography in P. A. Schilpp, *Albert Einstein, Philosopher-Scientist* (Evanston, Ill., 1949); from Jagdish Mehra, *The Solvay Conferences on Physics* (Dordrecht and Boston, 1975); and from A. Eucken, *Die Theorie der Strahlung und der Quanten* (Halle, 1914), which is a detailed report on the First Solvay Conference.

2. *Science* 49 (1929): 248-249. Einstein observes that, whatever Newcomb achieved, he could of course not explain the irregularity of the perihelion of Mercury because only General Relativity could cope with this anomaly. In an assessment of Newcomb's achievements this was an odd observation to make, since Newcomb died in 1909, years before there was a theory of General Relativity. Newton could not have explained it either.

3. Marjorie Hope Nicolson, *Newton Demands the Muse: Newton's "Opticks" and the Eighteenth-Century Poets* (Princeton, 1946). See also the "Preface" by I. Bernard Cohen in the edition of the *Opticks* by Dover Publications (New York, 1952). This edition also has a valuable introduction by Sir Edmund Whittaker.

4. Died at age forty-five.

5. H. D. Smyth, *Atomic Energy for Military Power* (Washington, D.C., 1945). This book, a best-seller, was, in effect, a government publication.

6. W. de Sitter, *Kosmos* (Cambridge, Mass., 1932), p. 113.

7. Niels Bohr, *Atomic Theory and the Description of Nature* (Cambridge, 1934), p. 16.

8. *Ibid.*

9. Salomon Bochner, "Mathematical Reflections," *The American Mathematical Monthly* 81 (1974): 827-857, especially p. 850.

10. Bohr, *Atomic Theory*, pp. 1-20.